A sub-pixel resolution enhancement model for multiple-resolution multispectral images

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Super-Resolution of Sentinel-2 multispectral images

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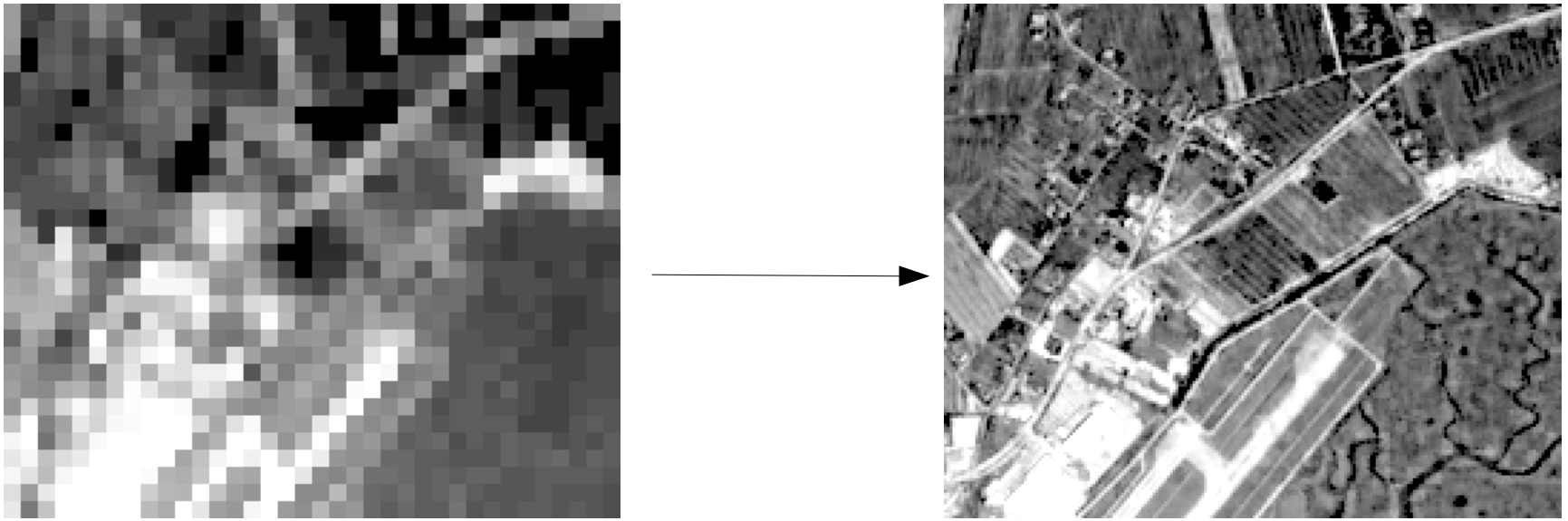
Classification of MODIS data with : A. Garg, D. Singh, IIT Roorkee, India

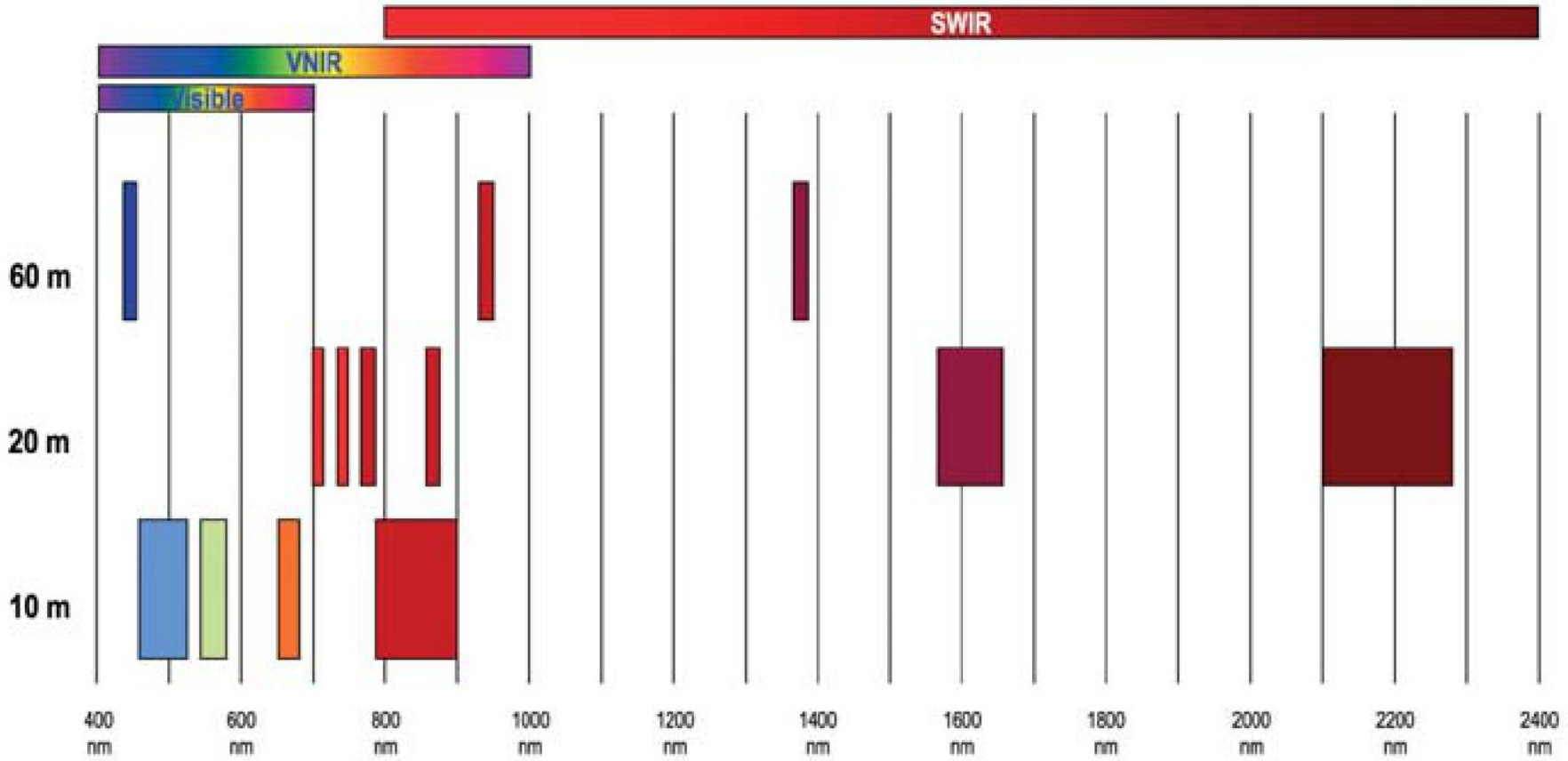


EGU General Assembly, Vienna, April 17-22, 2016

Sentinel-2

ESA Satellite, launched in June 2015

13 spectral bands at different resolutions : 60m/pixel, 20m/pixel, 10m/pixel



Goal : put all bands at 10m/pixel

Available test data (fall 2015)

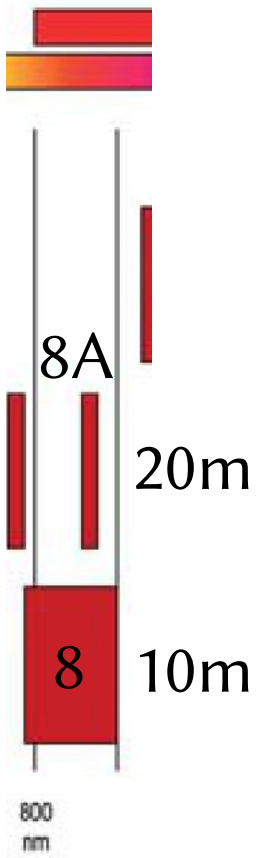
R,G,B bands
at 10m/pixel

Around
Venice

Result 20m → 10m

Example : Near infrared, Band 8A (20m), comparable to Bande 8 (10m)

Large band à 10m, narrow spectral band at 20m (targets vegetation)

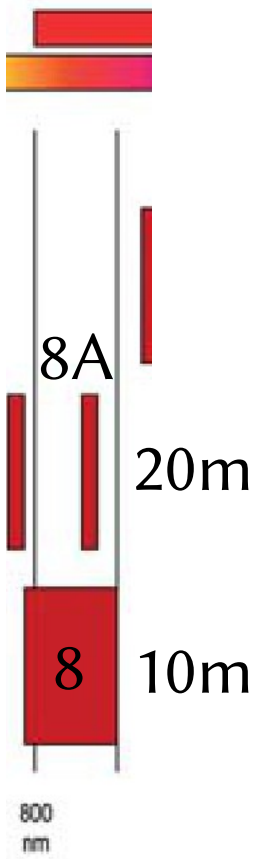


Original Band 8A (20m)

Result 20m → 10m

Example : Near infrared, Band 8A (20m), comparable to Bande 8 (10m)

Large band à 10m, narrow spectral band at 20m (targets vegetation)

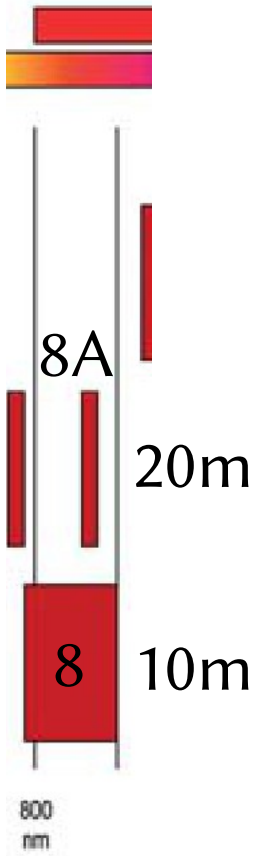


Bande 8A
résolue
à 10m

Résultat 20m ⟶ 10m

Example : Near infrared, Band 8A (20m), comparable to Bande 8 (10m)

Large band à 10m, narrow spectral band at 20m (targets vegetation)

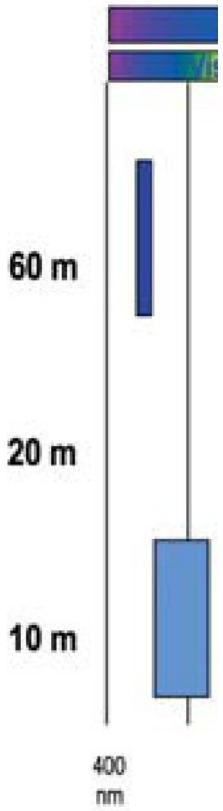


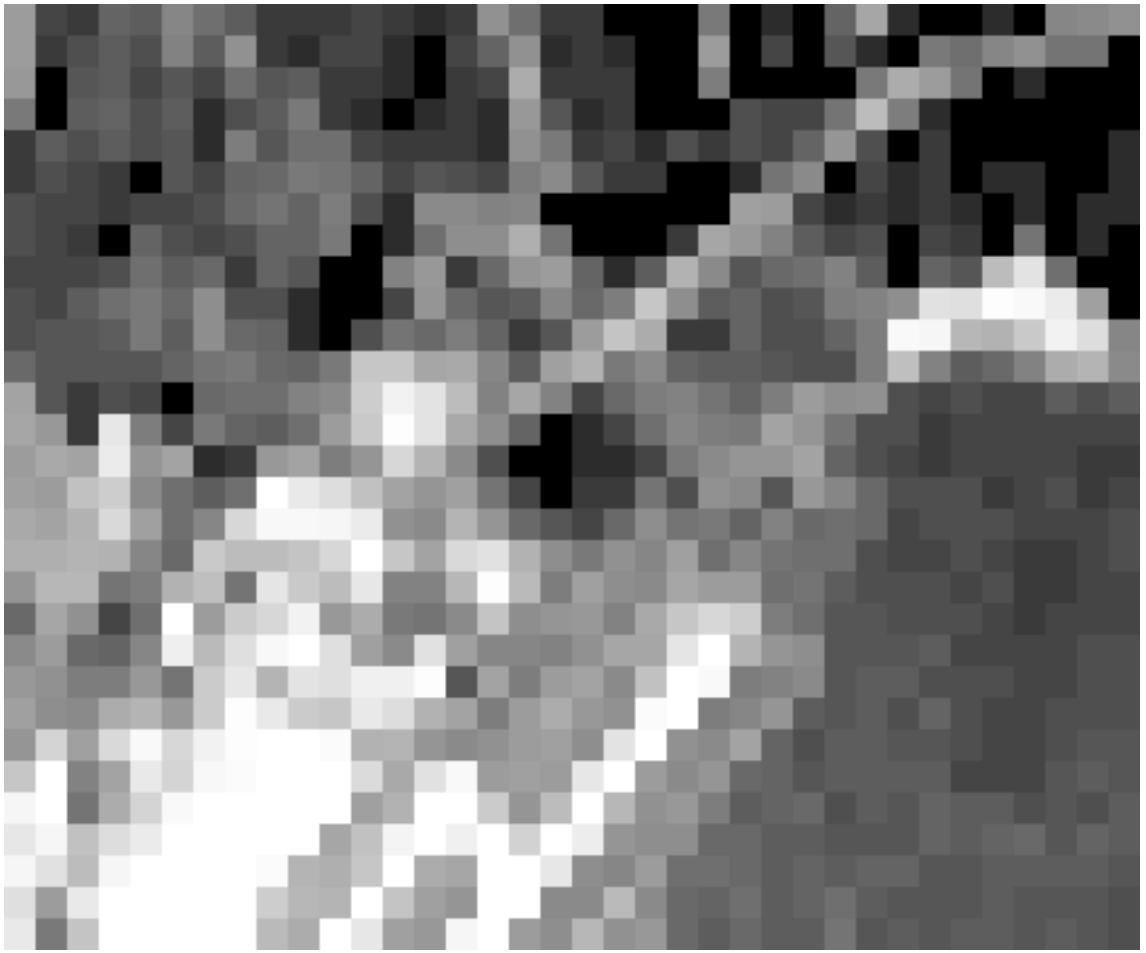
Bande 8
at
10m

Résultat 60m ⟶ 10m

Example : Visible light, Bande 1 (60m, violet),

To compare with band 2 (10m, blue) ?



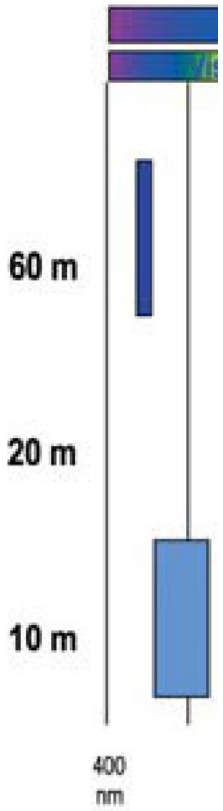


Original
Band 1
60m

Résultat 60m ⟶ 10m

Example : Visible light, Bande 1 (60m, violet),

To compare with band 2 (10m, blue) ?

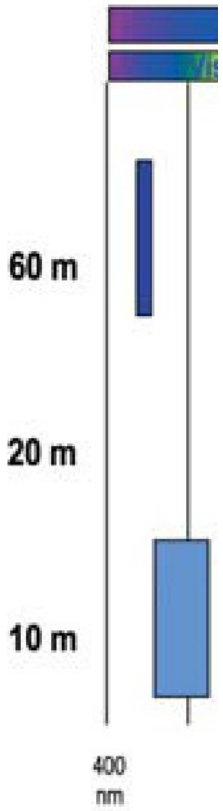


Super-resolved Band 1 at 10m

Résultat 60m ⟶ 10m

Example : Visible light, Bande 1 (60m, violet),

To compare with band 2 (10m, blue) ?



Original Bande 2 at 10m (blue, not violet)


Original 60m band 1


Super-resolved 60m band 1


Original 60m band 9


Super-resolved 60m band 9

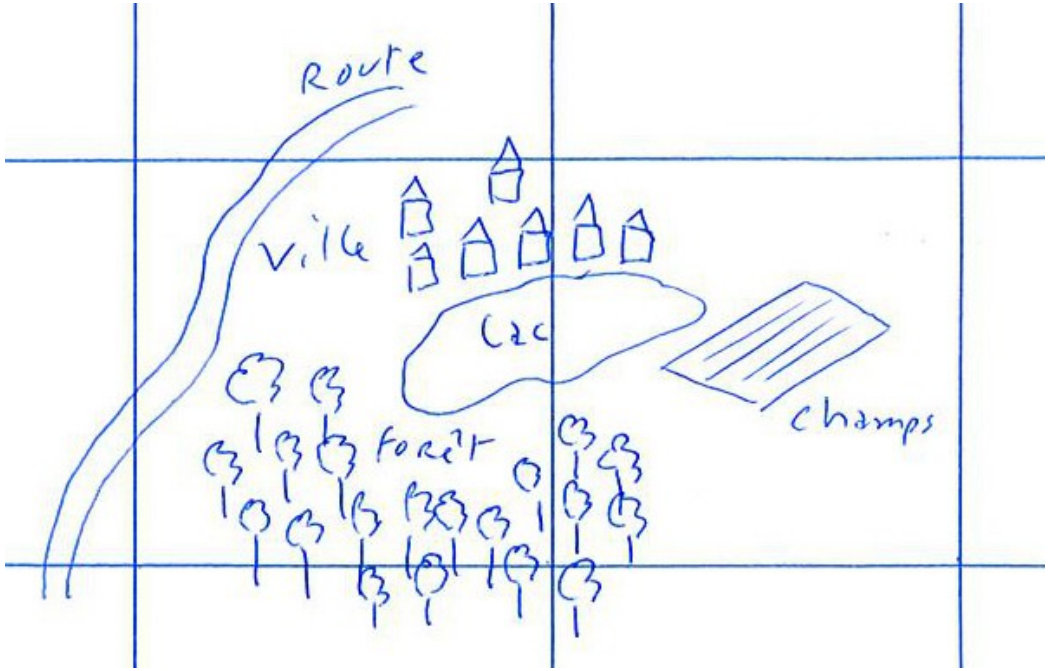
Method

Separating color from geometry

- Pixel = mix of different elements
- Mixing information = independent from the spectral band
- Color information information = specific to each band

Pixel boundaries are arbitrary

- Some information is also shared between nearby neighbors.

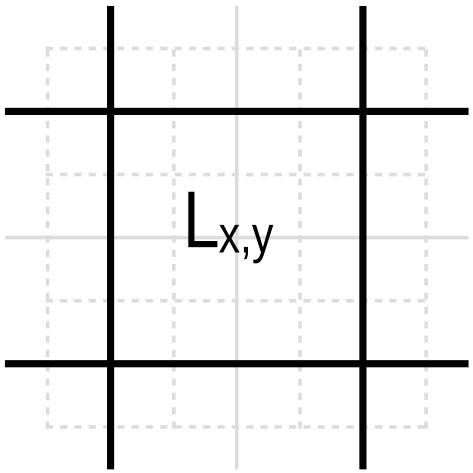


Too much pixel variability
$\Longrightarrow$ no long-distance information
for inferring sub-pixels
$\Longrightarrow$ Local model, $\neq$ wavelet for ex.

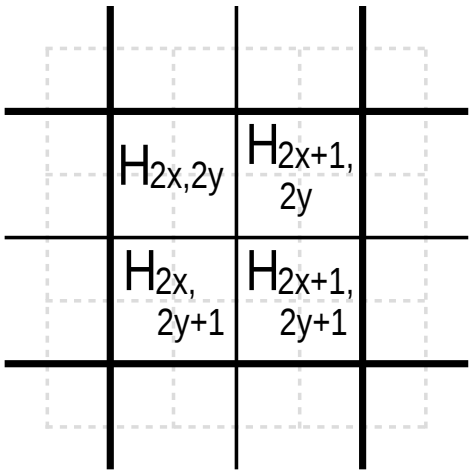
For 20m → 10m

The problem

Available low-resolution pixel



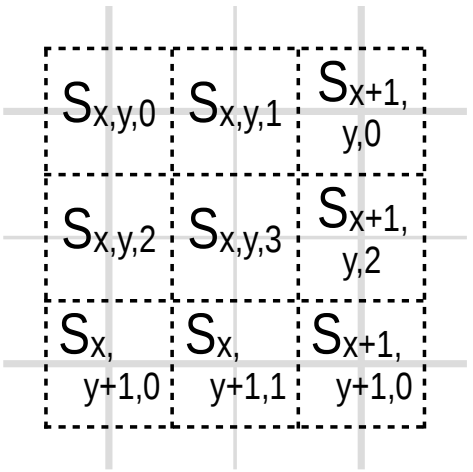
To divide in 4 pixels of higher resolution



Constraint: $\langle H \rangle = L$
$\Longrightarrow$ 3 free paramters / pixel

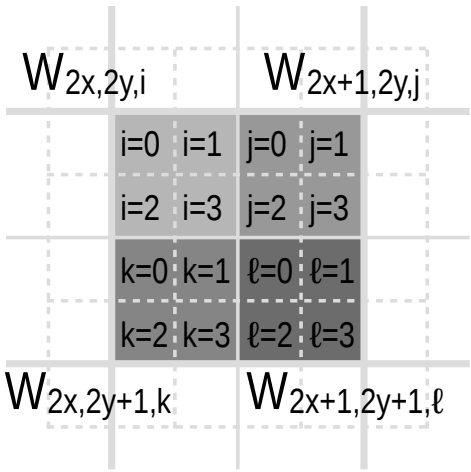
The model

Shared values beween neighbor pixels



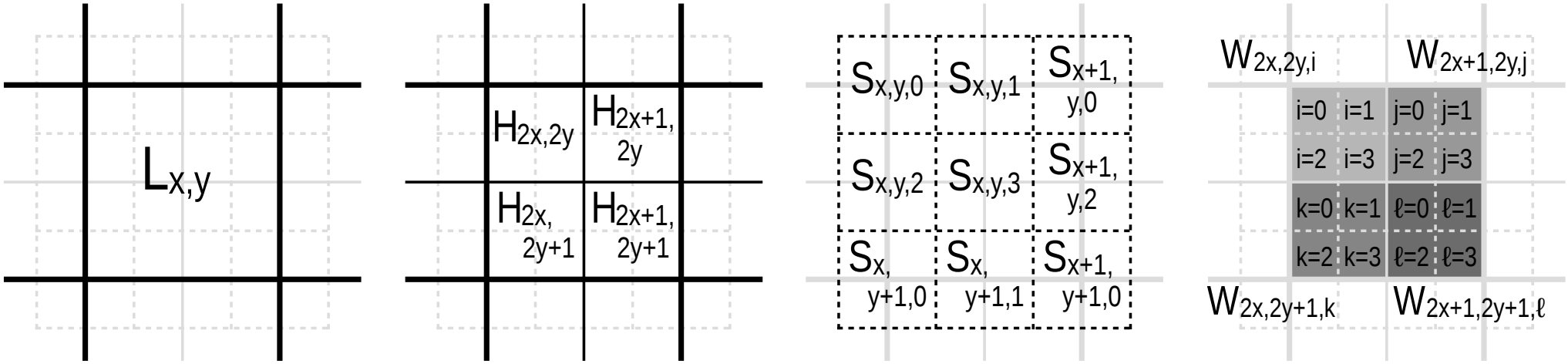
Depend on the spectral band

Weights = proportion of these shared values comprising the pixel



Shared between spectral bands
Constraint: $\Sigma w = 1$

Pour 20m ⟶ 10m



Step 1: Fit S, W using the 4 band at 10m

- H available ⟹ 1 parameter S / pixel at 10m is fixed ⟹ no free parameter for S
- 4 W per pixel at 10m, but 3 free parameters and 4 band ⟹ Least squares OK

Step 2: Find S for the 20m bands, W being fixed (band-independent)

- 2.1 (learning inter-pixels): Fit $S_L = \Sigma\ p_L \times L$, using neighbors on averaged 10m bands
- 2.2 (apply inter-pixels): Propagate $S_L = \Sigma\ p_L \times L$ on 20m bands
- 2.3 (apply details): Propage S/S_L of 10m bands ⟶ initial S value for 20m bands
- 2.4 (apply weights): H = W * S for 20m bands (+ renormalization ⟨H⟩ = L)

For 60m ⟶ 10m

Method cannot be applied as such: 36 sub-pixels at 10m / pixel at 60m!

Solution : Intermediate 60m ⟶ 20m step

- Quick analysis: – 9 sub-pixels at 20m, fixed average ⟹ 8 free parameters / pixel
  - 6 bands at 20m + 4 at 10m ⟹ 10 constraints (≈9 with similar B8/B8A)
  - + 3 free parameters per W, shared /10 bandes ≈ 0.3 param/pixel
  - ⟹ Global least square fit for S,W on 10 bands OK (≈8.3/9 param/pixel)
- + Same method for splitting geometry/color : Fit S, W at 20m, then S_L, then details.

60m original | 20m intermediate | 10m final

MODIS Data

2 NASA satellites, cloned

- Visible/infrared
- 2 bands at 250m/pixel, 5 bands à 500m/pixel
- 2 acquisitions / day (final Sentinel-2 scenario = 1 acquisition every 3-4 days)

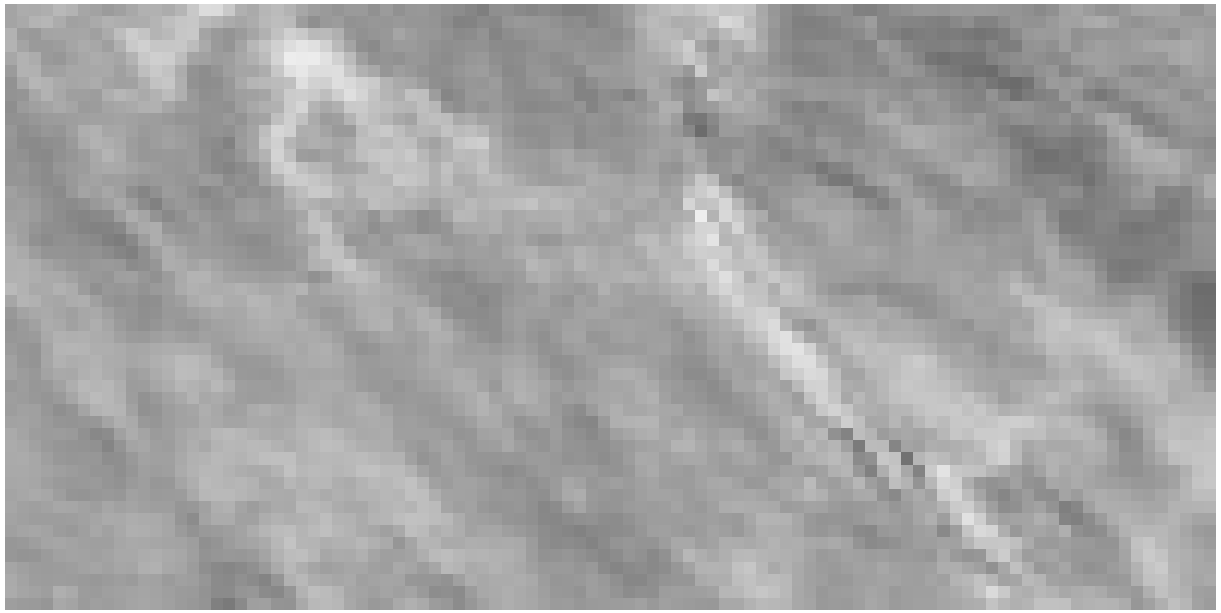
Method adaptation

- 2 bands of “high” resolution are not suffisant to fix the mixing weights W
- Hypothesis : The mixing geometry information (W) is unchanged over short times

  $\Longrightarrow$ Fix S, W over several acquisitions (min=2, more are best for clouds)

- E.g. using cloud-free bottom of atmosphere images processed with 16 day data, with overlapping 8-days windows

Exemple



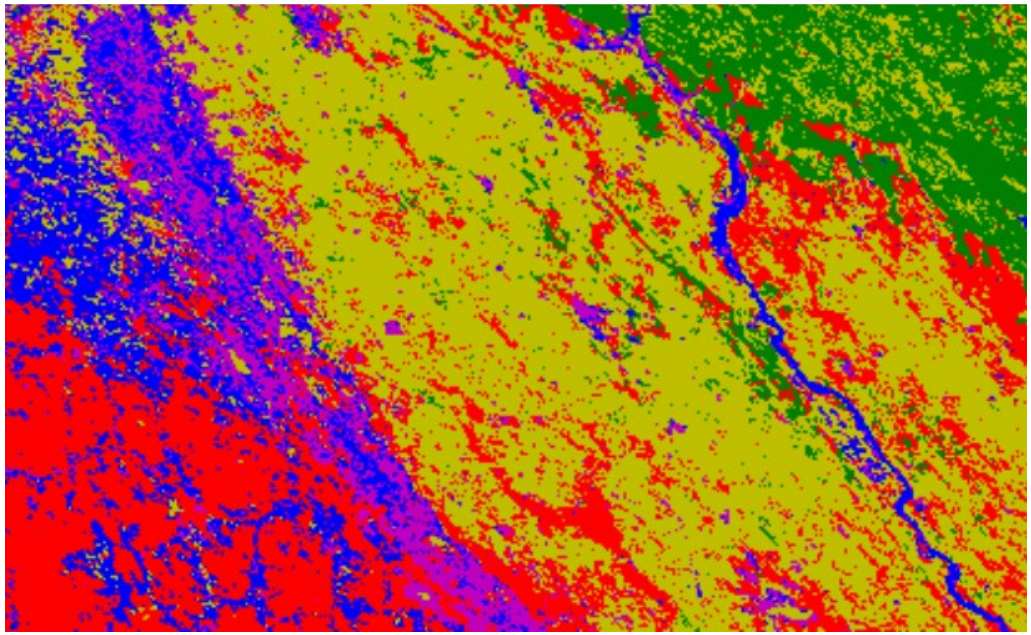
Original (infrared 1628-1652 nm)

Super-resolution 500m => 250m

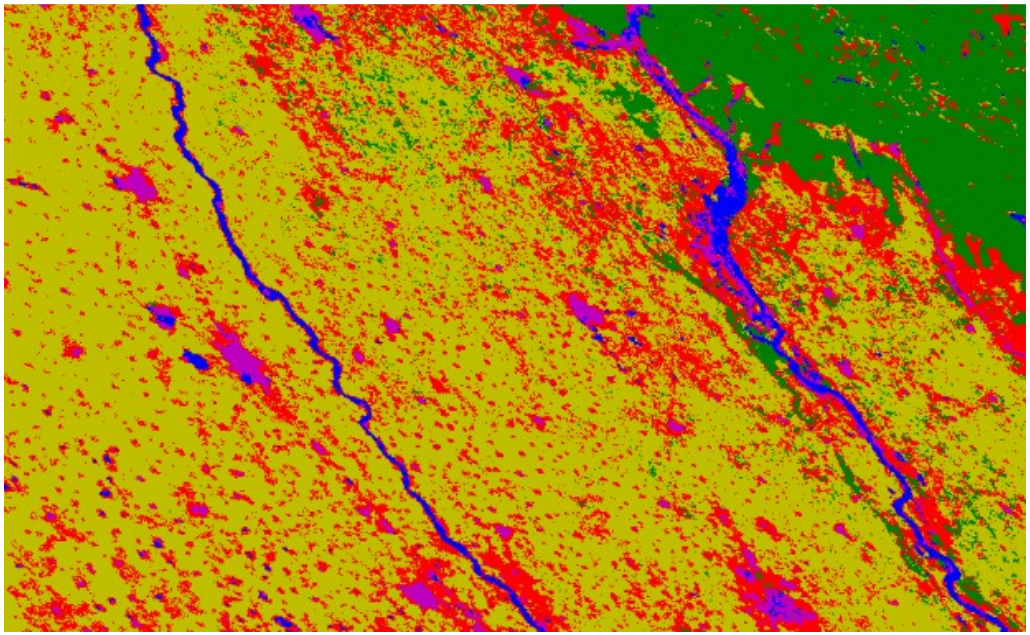
Land occupation

Study zone around Roorkee, 200km north of Delhi

classification with original 500m data



with 250 super-resolved data



Blue : water Purple : urban Green : Forest Yellow : Fields Red : bare soil